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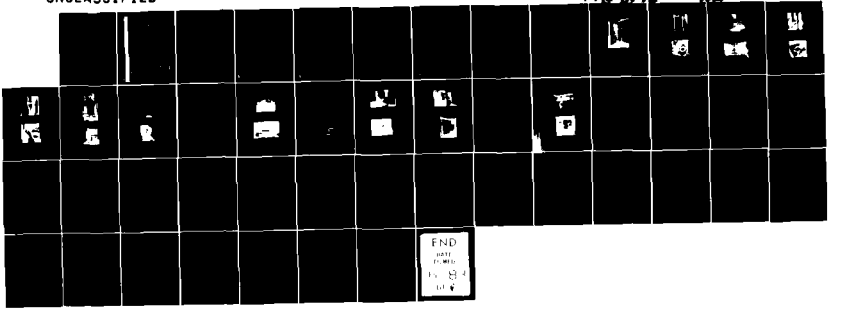

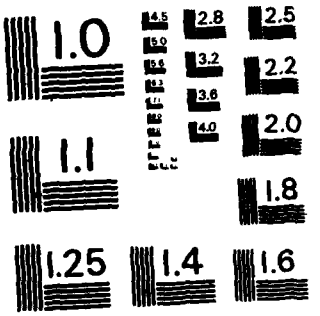

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DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORIES

MELBOURNE, VICTORIA

SYSTEMS REPORT 15

AUSTRALIAN TRI-SERVICE ANTHROPOMETRIC SURVEY, 1977:

PART 1. Survey planning, conduct, data handling and methods of analysis

by

K. C. HENDY

Approved for Public Release

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SUMMARY

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16. *ABSTRACT*

An anthropometric survey of approximately 3000 male members of the three Australian military branches was conducted during 1977. Part 1 of this nine-part document describes the choice of subject sample, the measurements, equipment, data handling, validation and analysis. Parts 2 to 9 describe the results for various uniquely identified groups.

A

CONTENTS

1. INTRODUCTION

An anthropometric survey of approximately 3000 male members of the three Australian military branches (Army, Navy and Air) commenced in January 1977. The measuring phase of this survey was completed in 11 months. The project was initiated by the Human Factors (Ergonomics) Sub-Committee of the Defence Standardisation Committee to establish a data base that could support an Australian Defence Standard on human engineering. Air Force Office accepted overall responsibility for the planning and conduct of the survey (through the RAAF Institute of Aviation Medicine, Point Cook) with assistance provided by Army and Navy Offices and the Aeronautical Research Laboratories (ARL).

Before proposing the project to the Defence Standardisation Committee, the Human Factors Sub-Committee searched for suitable existing data. With the exception of the 1971 survey of RAAF Aircrew (Ref. 1), previously published data appears to have been gathered specifically for the manufacture of clothing (Refs. 2 and 3) and therefore was of limited use for workplace and equipment design purposes. Apparently there had been no systematic gathering of anthropometric data, except for clothing manufacture, from either the Australian civilian or military populations prior to 1971.

The Tri-Service survey will be documented in two forms. Firstly, a report has been prepared by the survey team personnel (Ref. 4) detailing aspects of the day-to-day running and organising of a field trial of this magnitude. Secondly, ARL as the agency responsible for the scientific conduct of the survey together with the storage and analysis of the survey data, will report these aspects separately in a nine-part Establishment publication. This document is the first part of the publication and describes the scientific planning, the equipment and workstation used, data handling and methods of analysis. Parts 2 to 9 describe the survey results for various unique groups. The identification of these unique groups is described in Section 6 of this document.

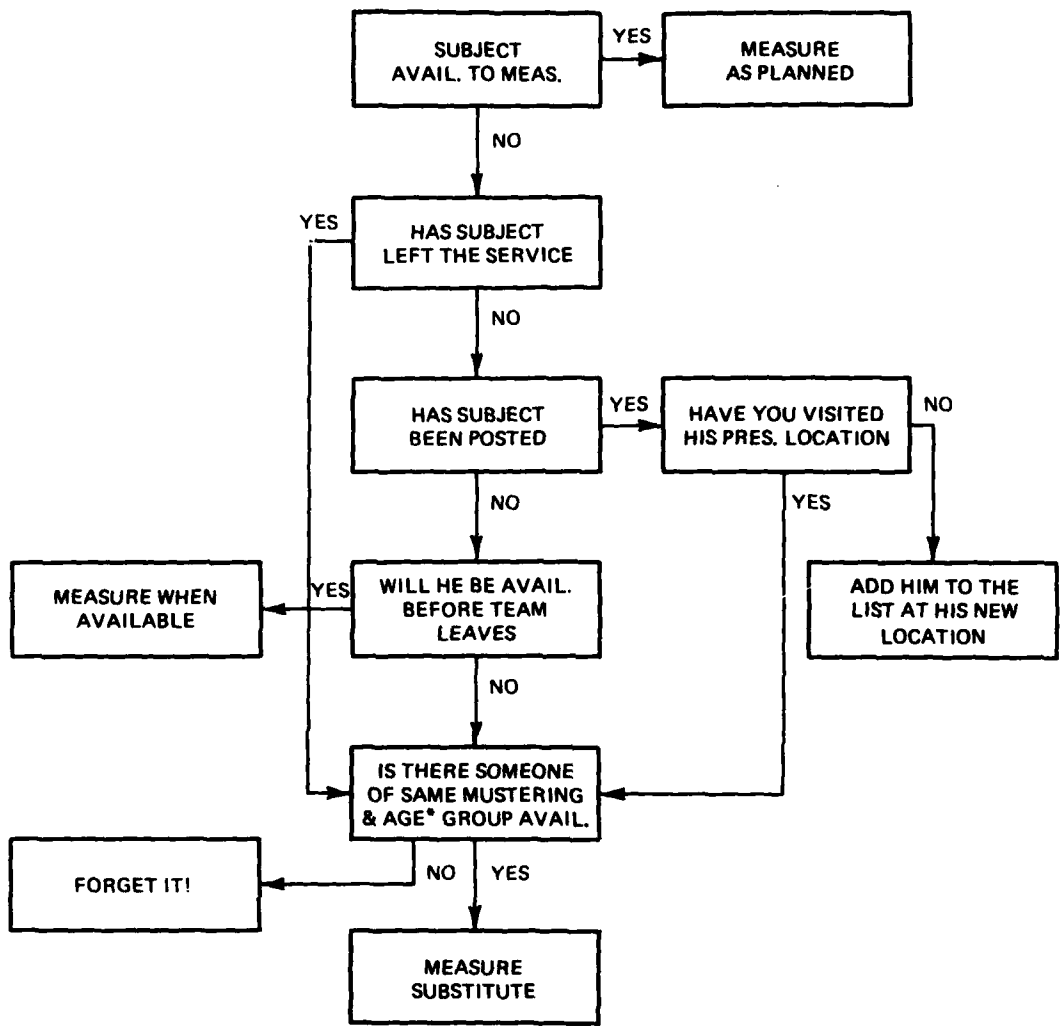
2. SUBJECT SAMPLING

Very little was known about the anthropometry of Australian military personnel. For example, there have been no previously published attempts to compare the populations of the three military branches (Army, Navy and Air Force) nor to test the homogeneity between members of different trade groups within the same service branch. Therefore, it was considered necessary for this survey to gather such data as would allow these types of comparisons to be made. Hence, various groups were identified that were associated with particular types of equipment and workplaces as follows:

(*a*) Army:
- (i) Weapon Users;
- (ii) Transportation;
- (iii) Clerks and Others;
- (iv) Aviation;
- (v) Catering;
- (vi) Technical Personnel.

(*b*) Navy:
- (i) Clearance Divers;
- (ii) Consolidation;*

* The Consolidation and Miscellaneous (see page 3) groups are made up of all those personnel not specifically covered by the other group designations.



*Take the subject's age in years (ignore months) and select a replacement whose age is within 2 years of the original subject's age. If there are several alternatives, select the one who is closest in age to the original subject.
E.g. if the missing subject is of age 26 years, select a replacement from the same functional group in the age range 24–28 years.

FIG. 1 FLOW CHART FOR THE SELECTION OF SUBSTITUTES.

(iii) Catering;
(iv) Fleet Air Arm;
(v) Submariners.

(c) Air Force:
(i) Air Traffic Controllers;
(ii) Aircrew;
(iii) Electronic Mustering;
(iv) Other Technical Musterings;
(v) Transportation;
(vi) Catering;
(vii) Miscellaneous.*

The standard errors of the 5th and 95th percentiles were estimated, as a function of group size, by assuming the measurements to be distributed Normally. The estimate was based on the formula (Ref. 5):

$$SE_{k\ \%ile} = \frac{(SD\sqrt{k(100-k)})}{100 f_k \sqrt{N}},$$

where:

k = the percentile value;

SD = the standard deviation;

f_k = ordinal value (Normal) at the kth %ile;

N = sample size;

SE = standard error of the kth %ile.

The data used for these computations came from a variety of sources, mostly non-Australian (UK or US). However, it was considered that the accuracy of the process was commensurate with the purpose. Using check-measure data from the 1970/71 RAF aircrew survey (Ref. 6), it was estimated that group sample sizes of 100 to 200 subjects would bring the standard errors of the 5th and 95th percentiles within the range of the expected measuring accuracy. Allowing for some wastage, a group sample size of 200 was used in the subsequent sampling procedure.

The names of subjects to be measured were selected from EDP personnel records. The selection procedure was such that sample age profiles were matched to the age profiles of the parent groups from which they were selected. The mechanics of this procedure were as follows: all eligible members of a parent group were rank ordered by date of birth, then every nth member was selected for the sample so as to yield a sample size of approximately 200. Eligible members were male, full-time serving personnel (excluding apprentices, cadets) up to and including the rank of Lt. Colonel (or equivalent) located in mainland Australia but excluding South Australia, Western Australia and the Northern Territory. Following sample selection, the names of subjects from all sample groups were recombined and printed out by unit location.

As it was anticipated that there would be situations when certain subjects, selected by the process just described, would not be available for measuring (on exercise, leave, discharged, posted, etc.) a method of substitution was used to maintain sample numbers. The procedure used was to measure a substitute, from the same trade group, whose age was within ± 2 years of the age of the subject originally selected. This process is shown schematically in Figure 1. The final substitution rate for this survey was 40·7% (for all branches and all groups) while the wastage was only 3·7% (i.e. the subject was not available nor could a suitable substitute be provided).

3. MEASUREMENTS SELECTED

The selection of measurements to be included in the survey became a trade-off between the requirement to establish a viable data base and the length of time necessary to complete the survey. The 32 parameters finally chosen were considered to provide data that would answer

* See footnote page 1.

FIG. 2 ANTHROPOMETRIC MEASURING RIG.

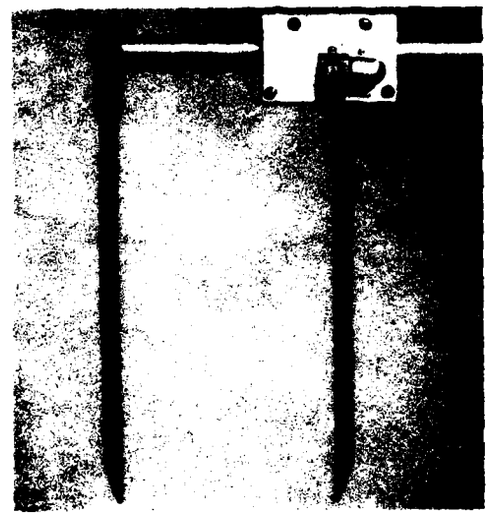


FIG. 3 HOLTAIN 'HARPENDEN' SLIDING CALIPERS

FIG. 4 SALTER 'MODEL 209' SPRING SCALES

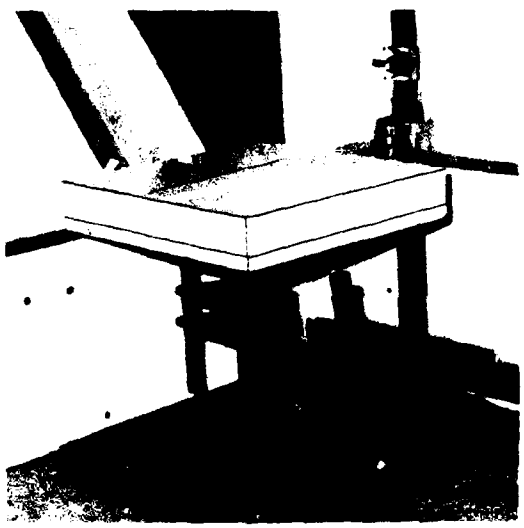


FIG. 5 ADJUSTABLE HYDRAULIC STOOL

FIG. 6 BUTTOCK-HEEL MEASURING RIG

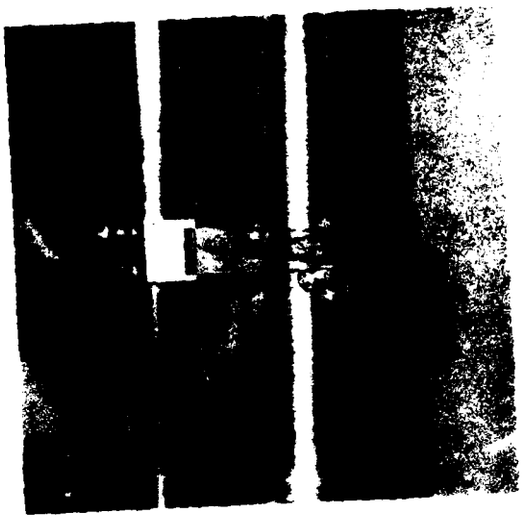


FIG. 7 HAND CONE

FIG. 8 FOOT BOX

FIG. 9 GLASS-FIBRE TAPES

FIG. 10 SHOULDER-MARK TEMPLATE

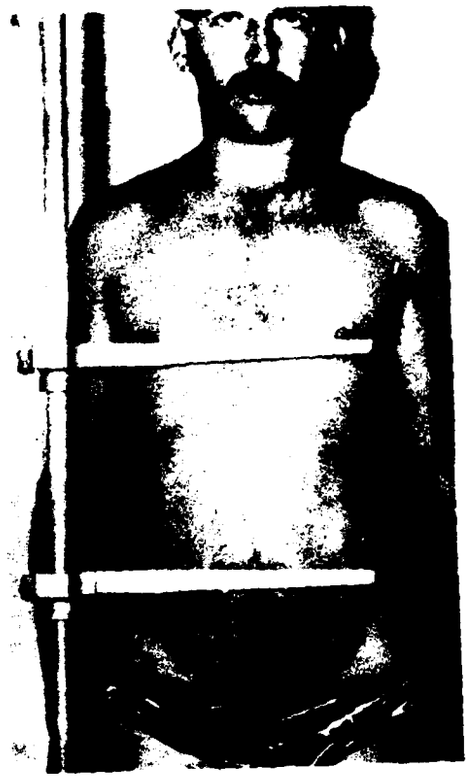


FIG. 11 CHEST-AND WAIST-MARK GAUGE

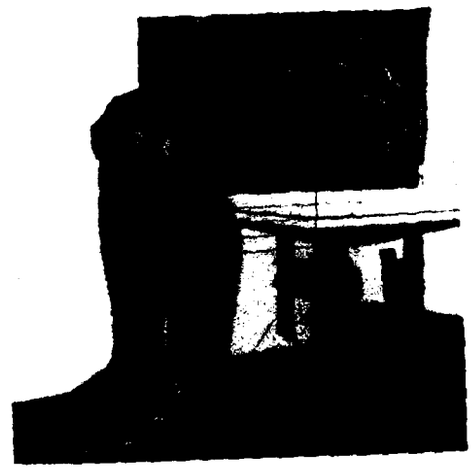


FIG. 12 LEG-POSITION GAUGE

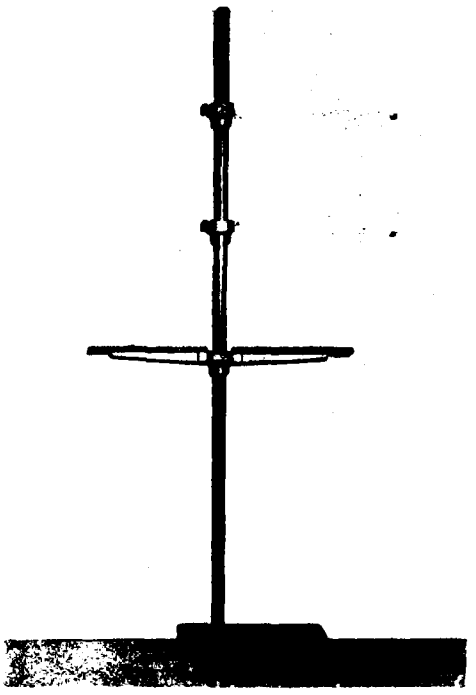


FIG. 13 HAND-STEADY WITH EYE-AND CHEST-SIGHT LINES

FIG. 14 EYE HEIGHT ATTACHMENT

the basic requirements of workplace designers (how tall, how wide, how deep, limb lengths, trunk circumferences and basic head, hand and foot dimensions). These measurements, together with their definitions appear in Appendix I of this Report. Because of the type of measuring apparatus envisaged for this project, the techniques described in the definitions tend to be similar to those used in the 1970/71 survey of 2000 RAF aircrewmen (Ref. 6).

With the parameter set determined, the measuring sequence was arranged. A considerable effort was made to streamline the data gathering process (both in time and effort) and to minimise errors in using equipment. To this end the measuring sequence was established according to the following criteria:

(i) minimal subject movement between measurements;
(ii) convenience of the measuring team (e.g. avoidance of continual changes to posture or prolonged bending); and
(iii) elimination of unnecessary adjustments to equipment (i.e. the sequence was arranged so that the previous measurement generally left the equipment positioned for the next measurement).

Once the sequence was determined, the equipment and workstation layout was designed specifically to accommodate it.

4. MEASURING APPARATUS

The measuring apparatus consisted of the following items:

(i) anthropometric measuring rig (Fig. 2);
(ii) Holtain 'Harpenden' sliding calipers (Fig. 3);
(iii) Salter 'Model 209' spring scales (Fig. 4);
(iv) adjustable hydraulic stool (Fig. 5);
(v) buttock–heel measuring rig (Fig. 6);
(vi) hand-cone (Fig. 7);
(vii) foot-box (Fig. 8); and
(viii) glass-fibre tapes (Fig. 9).

A variety of aids was used to streamline the marking and measuring techniques. These aids were:

(i) shoulder mark template (Fig. 10);
(ii) chest and waist mark gauge (Fig. 11);
(iii) leg-position gauge (Fig. 12);
(iv) eye and chest sight lines (Fig. 13);
(v) hand-steady (Fig. 13); and
(vi) eye height attachment (Fig. 14).

All lengths were measured in millimetres and mass was measured in kilograms.

4.1 Air-transportable Cabin

All the measuring apparatus was contained within an air-transportable cabin. The cabin interior was air-conditioned (heating and cooling) to provide both a comfortable environment for the subjects and measuring team, and to thermally stabilise the equipment. Thermostatic control maintained the cabin interior at approximately 21°C. The cabin was mounted on a trailer, pulled by a prime mover (Fig. 15). In this way the measuring rig was transported to all of the scheduled units with the exception of Townsville. For the Brisbane–Townsville–Brisbane leg of the survey, the cabin was removed from the trailer and transported in an RAAF C-130 (Hercules) aircraft.

The measuring sequence was validated by a brief pilot survey preceding the main experiment. From the pilot survey came a final sequence to be used in determining the workspace layout for the cabin. Initially the cabin was unfurnished although existing door and window positions, together with the requirement to provide a thoroughfare during the airlift, offered some constraint on internal layout. In order to increase subject measuring rate a multi-workstation philosophy was pursued. The space limitations of the cabin (5·8 m × 2·9 m × 2·2 m) and the constraints on layout restricted the number of separate workstations to two. Hence, the cabin

FIG. 15 AIR TRANSPORTABLE CABIN AND TOWING UNIT

FIG. 16 TRAILER BED ANNEX

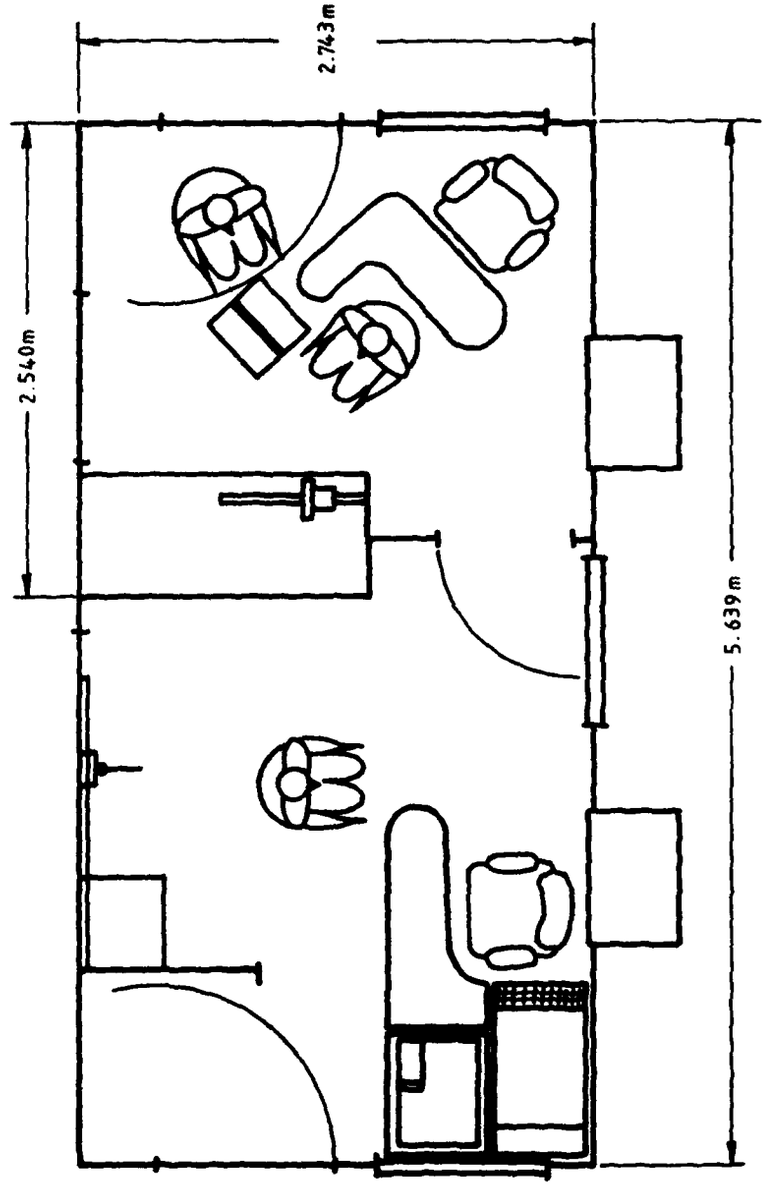


FIG. 17 CABIN LAYOUT

FIG. 18 ROOM 1 INTERIOR LAYOUT

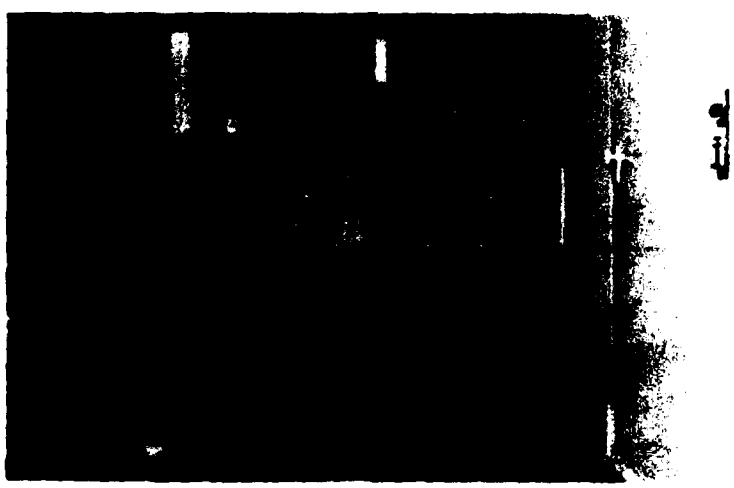


FIG. 19 ROOM 1 INTERIOR LAYOUT

FIG. 20 ROOM 2 INTERIOR LAYOUT

FIG. 21 ROOM 2 INTERIOR LAYOUT

was divided into two rooms by the addition of a partition wall. A door provided access between the rooms.

The measurements to be taken were allocated to the two rooms (according to the previously determined sequence) so that a subject's time would be divided approximately equally between the rooms (slightly more time was spent in the first room to prevent 'bunching' of subjects). Thus with the exception of the first and last subject during any measuring session, this arrangement allowed two subjects to be measured simultaneously by having both rooms occupied.

At the rear of the trailer a canvas covered annex provided changing facilities and space for various functions (Fig. 16). Detachable steps provided easy access to the bed of the trailer. A floor plan of the cabin is shown in Figure 17 with photographs of the interior layout in Figures 18 to 21.

4.2 Equipment Design

In designing the measuring equipment some attention was paid to the potential for errors in the data gathering sequence of the survey. In an effort to reduce the number of instrument reading errors, digital readouts were used wherever possible. With the exception of the foot-box, spring scales and the tape measures, all measuring devices were fitted with mechanically driven displays. The 'Harpenden' sliding calipers use a rack and pinion driven digital display in their standard form.

The measuring heads of the anthropometric rig, hand-cone and buttock–heel length rig were designed and built by ARL as variations on the 'Harpenden' principle (see Figs. 22, 7 and 23). Other items designed and built by ARL included the adjustable hydraulic stool, foot-box and measuring aids.

5. DATA HANDLING AND VALIDATION

As the group sample sizes for this survey were relatively small (approximately 200), it was considered essential to minimise the wastage of data due to incomplete or incorrect entries. Hence, it was intended that data checking and validation would be done immediately following subject measurement, by recording the information on hand-marked computer cards and processing via a marked card reader and DEC PDP 11/35 digital computer carried in the cabin. Therefore, data not satisfying the various checking routines could have been verified or corrected before the subject left the cabin. However, equipment and staffing difficulties in the critical period preceding the commencement of the survey finally caused this scheme, in its original form, to be abandoned. Instead, the data were handwritten on proformae sheets of the type shown in Figure 24. The order of the parameters in Figure 24 corresponds to the measuring sequence; further, the division of measurements into left- and right-hand columns corresponds to the allocation of parameters between the two workstations in the cabin.

The proformae sheets were sent to ARL at regular intervals during the survey (usually when leaving each main Base or Unit location) and the data entered to ARL's DECsystem-10 computer facility. The checking routines originally intended for 'on-site' validation were then applied to the data.

5.1 Data Validation Procedures

The types of test used to check the raw data were as follows:

(i) data were rank ordered and those values ranked highest and lowest were examined for the existence of obvious errors;

(ii) order relationships on various parameters were checked (e.g. Stature > Sitting Height) for each subject;

(iii) ratios involving two and three parameters were checked for internal consistency (e.g. Sitting Height/Stature); and finally

(iv) various parameters were checked to see if they lay within certain bounds empirically derived from other data sources (e.g. RAF 2000 aircrewmen).

With the exception of rank ordering, the tests applied to the data are summarised in Table 1. If the data for any subject failed any of these tests a printout was obtained listing the results for the tests failed, together with a complete listing of the subject's data file. This file was then

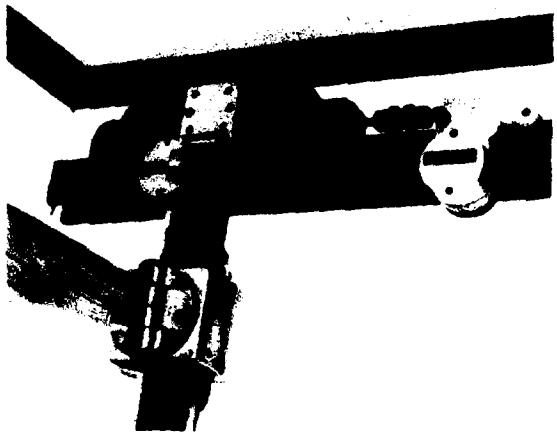


FIG. 22 ANTHROPOMETER MEASURING HEAD

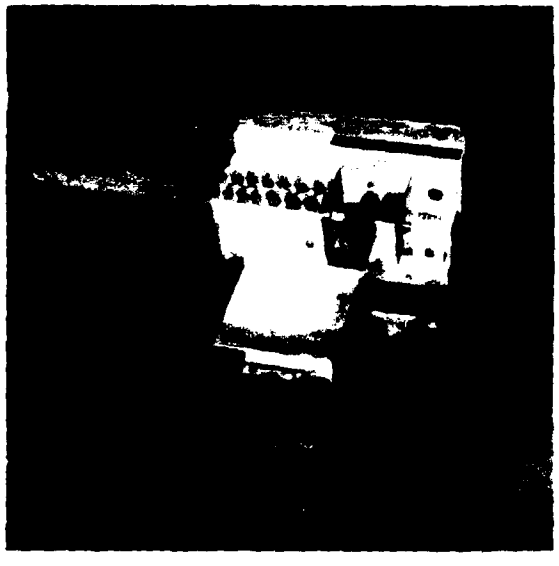


FIG. 23 BUTTOCK-HEEL RIG MEASURING HEAD

TRI-SERVICE ANTHROPOMETRIC SURVEY 1. No.

2. Functional Group ☐ Air ☐ Army ☐ Navy Group No. ☐

3. Date of Birth Month ☐☐ Year ☐☐

4. Handedness L A R

5. Foot Length	☐☐☐	20. Sitting Ht.	☐☐☐☐
6. Foot Breadth	☐☐☐	21. Eye Ht., Sitting	☐☐☐☐
7. Hand Length	☐☐☐	22. Shoulder Ht.	☐☐☐☐
8. Palm Length	☐☐☐	23. Acromial Ht.	☐☐☐☐
9. Hand Breadth	☐☐☐	24. Elbow Rest Ht.	☐☐☐
10. Thumb Length	☐☐	25. Popliteal Ht.	☐☐☐
11. Inner Hand Grip Diam.	☐☐	26. Bideltoid Breadth	☐☐☐
12. Head Circum.	☐☐☐	27. Hip Breadth	☐☐☐
13. Neck Circum.	☐☐☐	28. Functional Reach	☐☐☐☐
14. Chest Circum.	☐☐☐☐	29. Buttock-Knee Lth.	☐☐☐
15. Waist Circum.	☐☐☐☐	30. Thigh Clearance Ht.	☐☐☐
16. Buttock Circum.	☐☐☐☐	31. Stool Ht.	☐☐☐
17. Vertical Trunk Circum.	☐☐☐☐	32. Stature	☐☐☐☐
18. Buttock-Heel Length	☐☐☐☐	33. Crotch Ht.	☐☐☐☐
19. Mass	☐☐☐☐	34. Chest Depth	☐☐☐
		35. Head Breadth	☐☐☐
		36. Inter-Elbow Breadth	☐☐☐

FIG 24 PROFORMAE SHEET USED IN TRI-SERVICE SURVEY

TABLE 1
Test Procedures for Data Validation

No.	Test function	Lower	Upper
1	Age	17	50
2	Mass	50	115
3	Waist Circumference	675	1150
4	Neck Circumference	334	465
5	Stature > Sitting Height > Eye Height (sitting) > Shoulder Height (sitting) > Acromial Height (sitting) > Elbow Rest Height > Thigh Clearance Height	Rank Order	
6	Stature > Vertical Trunk Circumference	Rank Order	
7	Foot Length/Foot Breadth	2·35	3·01
8	Hand Length/Hand Breadth	2·00	2·67
9	Hand Length/Palm Length	1·62	1·86
10	Head Circumference/Head Breadth	3·40	4·10
11	Chest Circumference/Chest Depth	3·50	4·60
12	Chest Circumference/Buttock Circumference	0·89	1·13
13	Hip Breadth/Buttock Circumference	0·34	0·45
14	Inner Hand Grip Diameter/Thumb Length	0·63	0·91
15	Buttock–Heel Length/ (Buttock–Knee Length + Popliteal Height)	0·98	1·08
16	Crotch Height/Vertical Trunk Circumference	0·40	0·60
17	Sitting Height/Stature	0·48	0·56
18	Crotch Height/Stature	0·43	0·52
19	Crotch Height/Functional Reach	0·93	1·15
20	Bideltoid Breadth/Inter-Elbow Breadth	0·84	1·19
21	Popliteal Height/Stool Height	0·98	1·20
22	Stature/$\sqrt[3]{}$Mass	350	470

TABLE 2
Group Sizes for Analysis

Group description	Sample group size	Parent group size
ARMY		
Weapon Users	177	5161
Transportation	188	3980
Clerks and Others	190	9134
Aviation	88	123
Catering	190	1450
Technical Personnel	211	3872
NAVY		
Clearance Divers	82	102
Consolidation	185	8997
Catering	155	498
Fleet Air Arm	178	209
Submariners	169	359
AIR FORCE		
Air Traffic Controllers	129	155
Aircrew	190	896
Electronic Mustering	165	2658
Other Technical Musterings	167	3033
Transportation	114	434
Catering	198	511
Miscellaneous	169	5639

examined for a possible explanation for the discrepancy. If the data appeared to be internally consistent (e.g. large mass together with large girth measurements) no further action was taken. However, if the data were not reconcilable and the subject was not available for a check measure, all data from that subject were eliminated from further analysis. As a result of these checks 21 data cards were discarded. The resulting group sizes for analysis are shown in Table 2, together with the number of eligible subjects forming the parent groups from which they were chosen.

6. CONSOLIDATION OF GROUPS

The Kolmogorov–Smirnov two-sample test (Ref. 7) was used to establish the uniqueness of the original 18 groups. It was decided that only those groups showing consistent and significant differences (at the 0·01 level of statistical significance) would be segregated for final separate analysis. In general, only intraservice comparisons were considered in all combinations although several interservice groups, with a potentially strong commonality, were also included in the computations (e.g. aircrew, transport and technical groups).

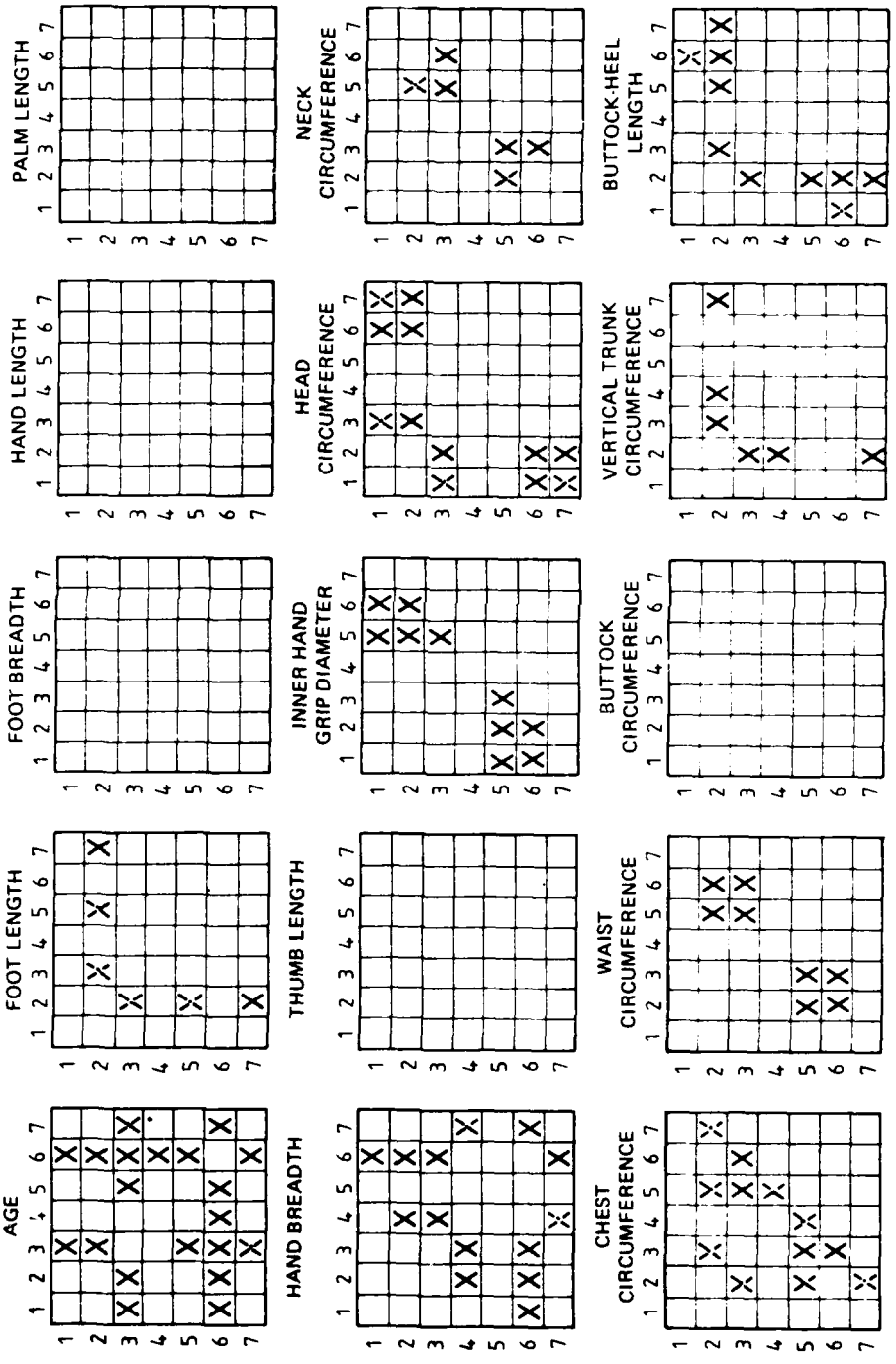
6.1 Intraservice Comparisons

The results of the Kolmogorov–Smirnov two-sample test for intraservice data are shown in Tables 3, 4 and 5. The solid cross represents significance at the 0·01 level, while the broken cross corresponds to significance at the 0·025 level.

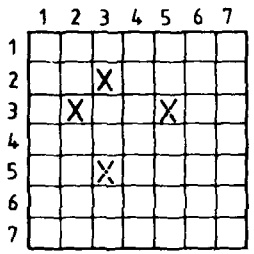
TABLE 3: INTRASERVICE COMPARISONS – AIR

GROUPS

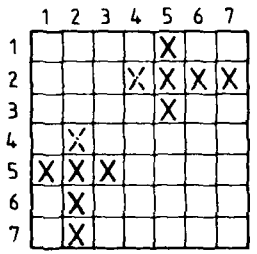
1. AIR TRAFFIC CONTROLLERS
2. AIRCREW
3. ELECTRONIC TECHNICIANS
4. TECHNICAL PERSONNEL
5. TRANSPORTATION
6. COOKS
7. MISCEL.



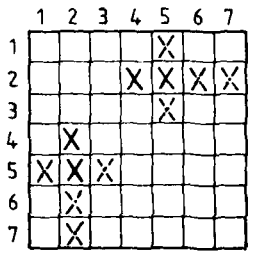
MASS



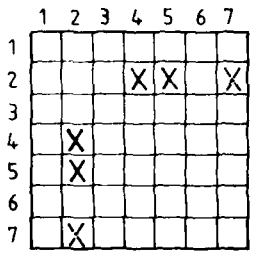
SITTING HEIGHT



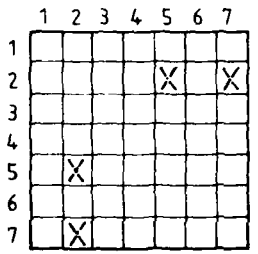
EYE HEIGHT, SITTING



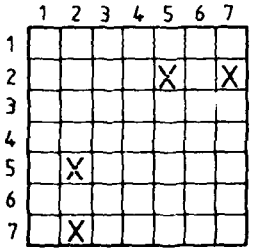
SHOULDER HEIGHT



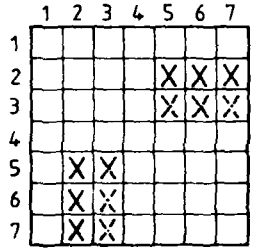
ACROMIAL HEIGHT



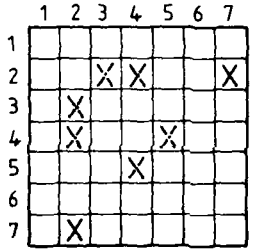
ELBOW REST HEIGHT



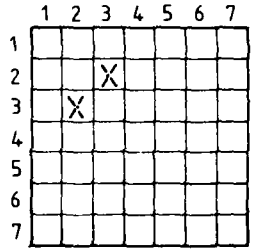
POPLITEAL HEIGHT



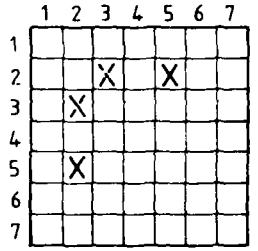
BIDELTOID BREADTH



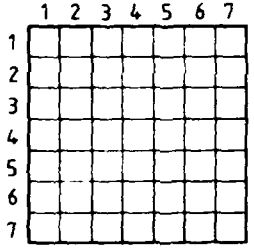
HIP BREADTH



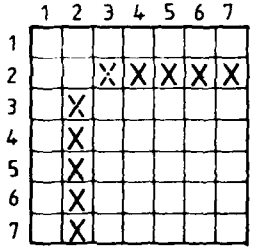
FUNCTIONAL REACH



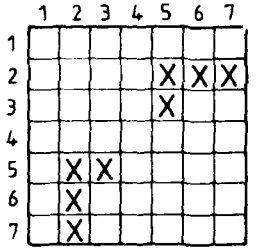
BUTTOCK-KNEE LENGTH



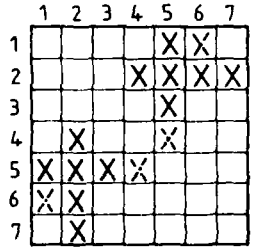
THIGH CLEARANCE HEIGHT



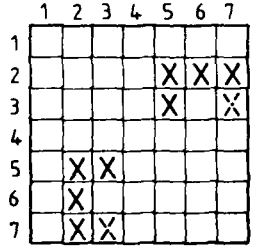
STOOL HEIGHT



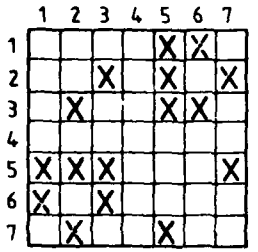
STATURE



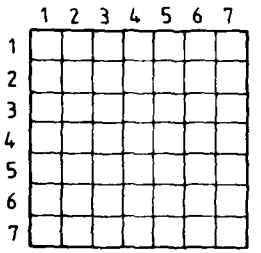
CROTCH HEIGHT



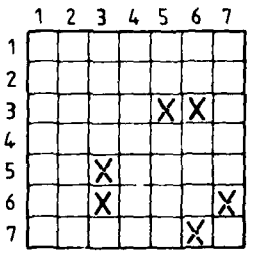
CHEST DEPTH

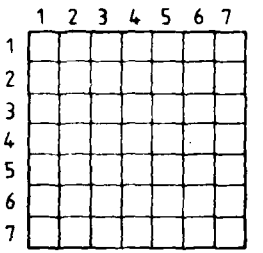


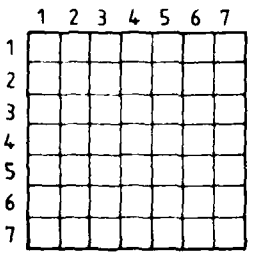
HEAD BREADTH

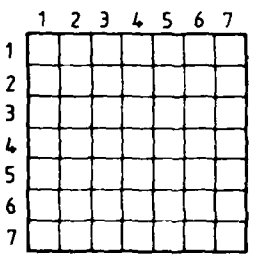


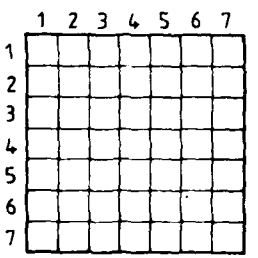
INTER-ELBOW BREADTH

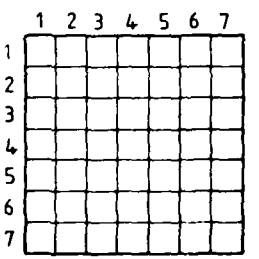


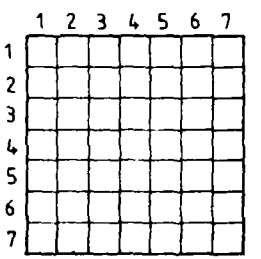


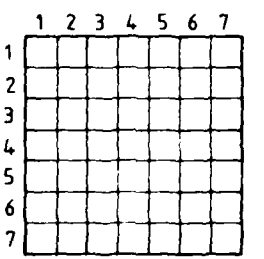


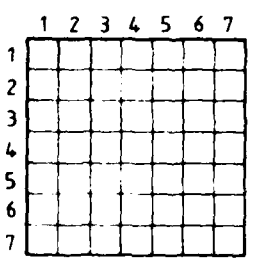


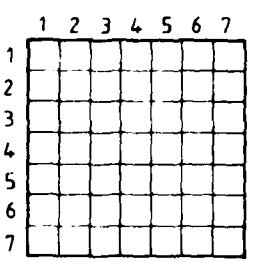


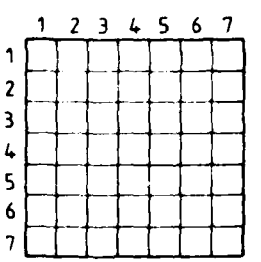


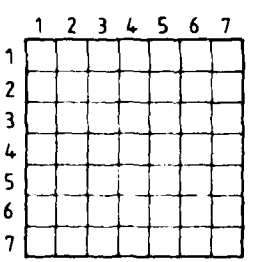












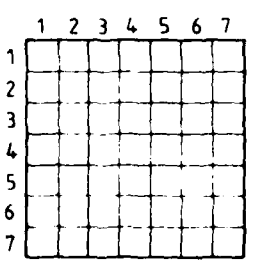
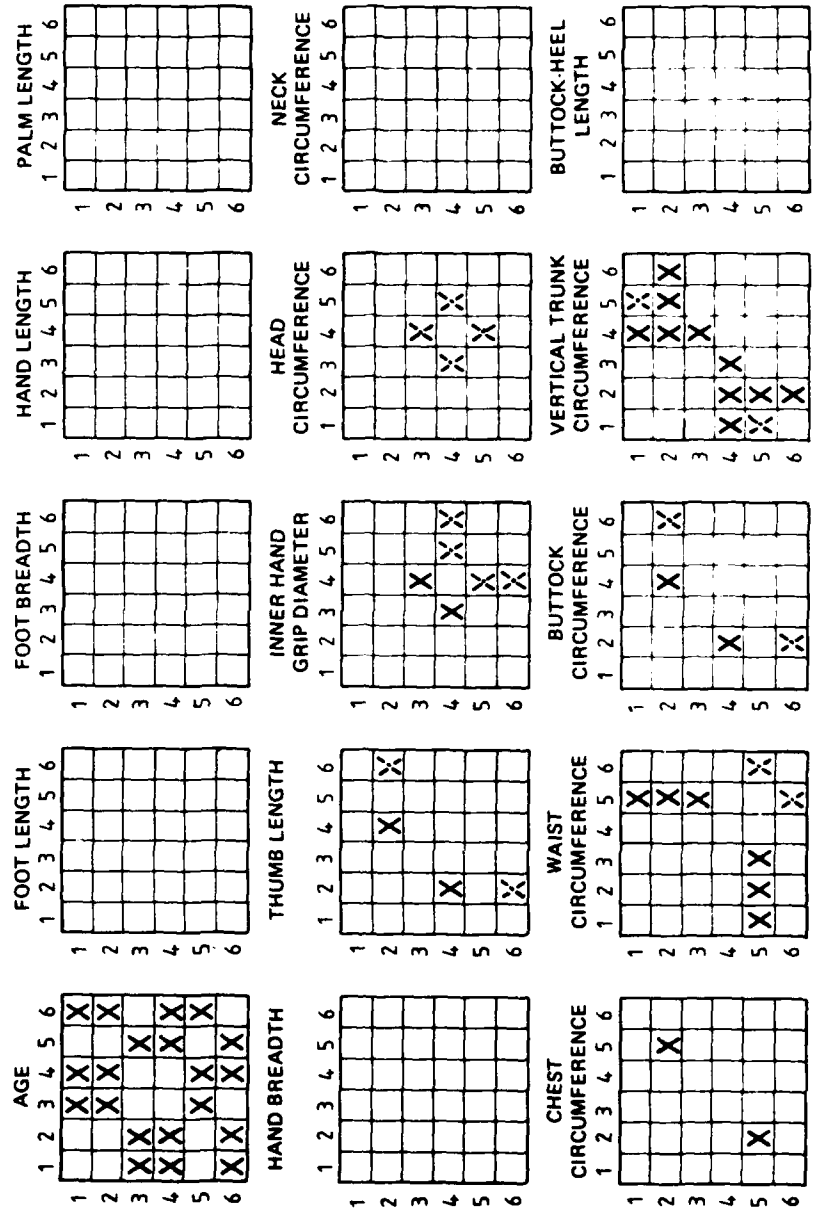
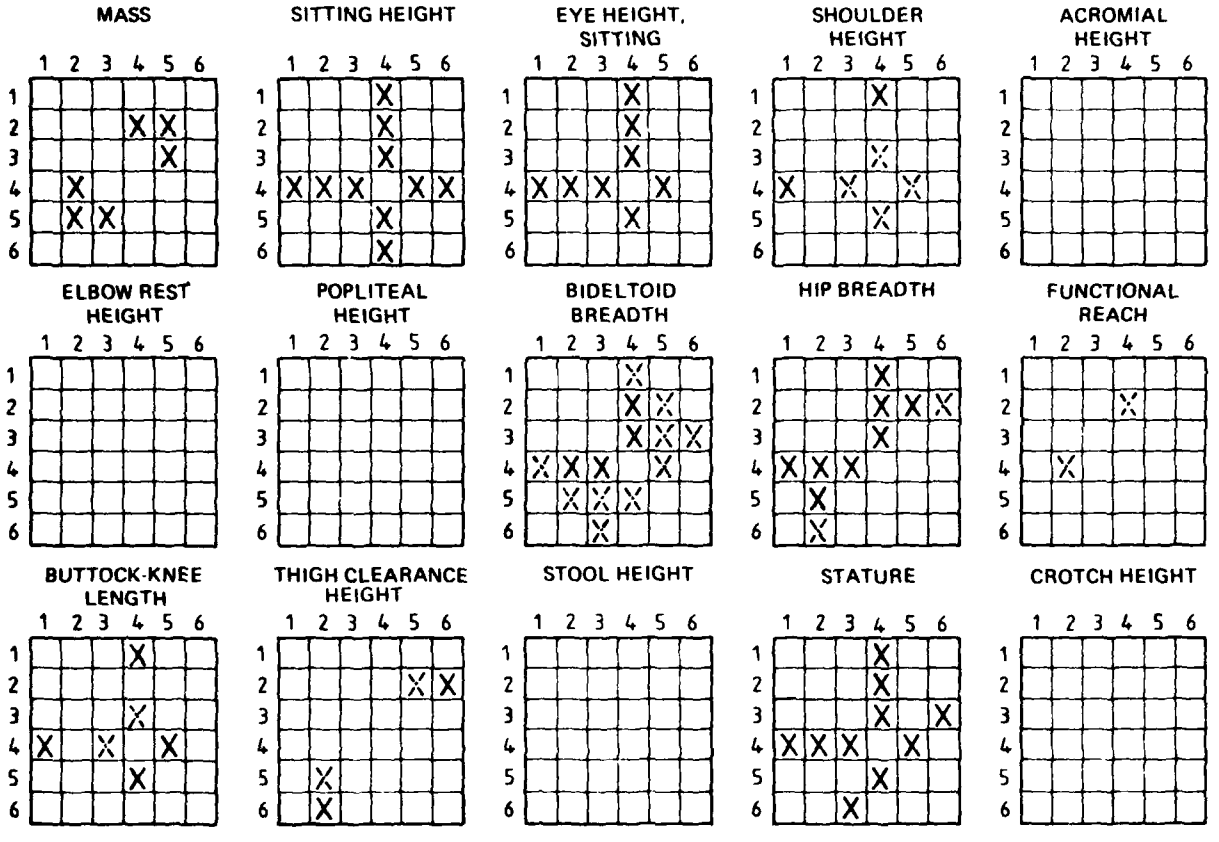


TABLE 4: INTRASERVICE COMPARISONS – ARMY

GROUPS
1. WEAPON USERS
2. TRANSPORTATION
3. CLERKS & OTHERS
4. AVIATION
5. COOKS
6. TECHNICAL PERSONNEL




MASS
SITTING HEIGHT
EYE HEIGHT, SITTING
SHOULDER HEIGHT
ACROMIAL HEIGHT
ELBOW REST HEIGHT
POPLITEAL HEIGHT
BIDELTOID BREADTH
HIP BREADTH
FUNCTIONAL REACH
BUTTOCK-KNEE LENGTH
THIGH CLEARANCE HEIGHT
STOOL HEIGHT
STATURE
CROTCH HEIGHT

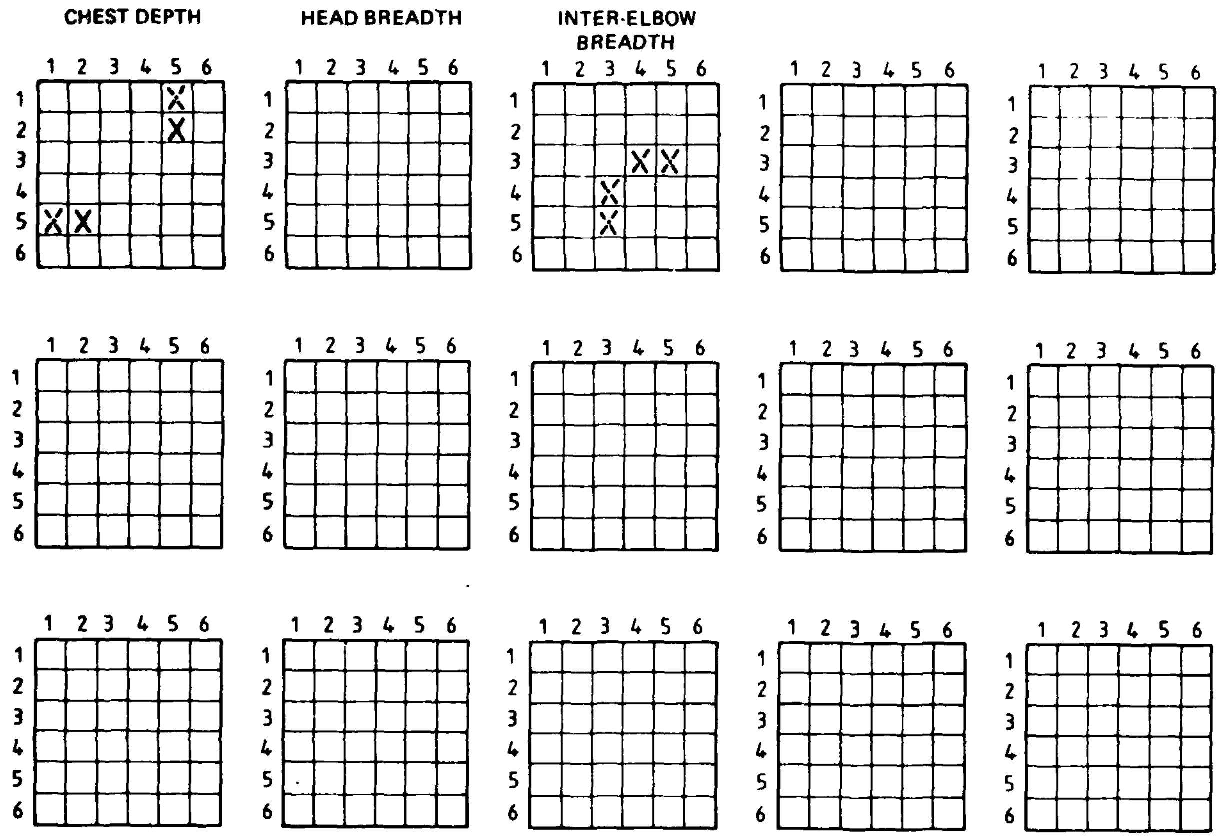
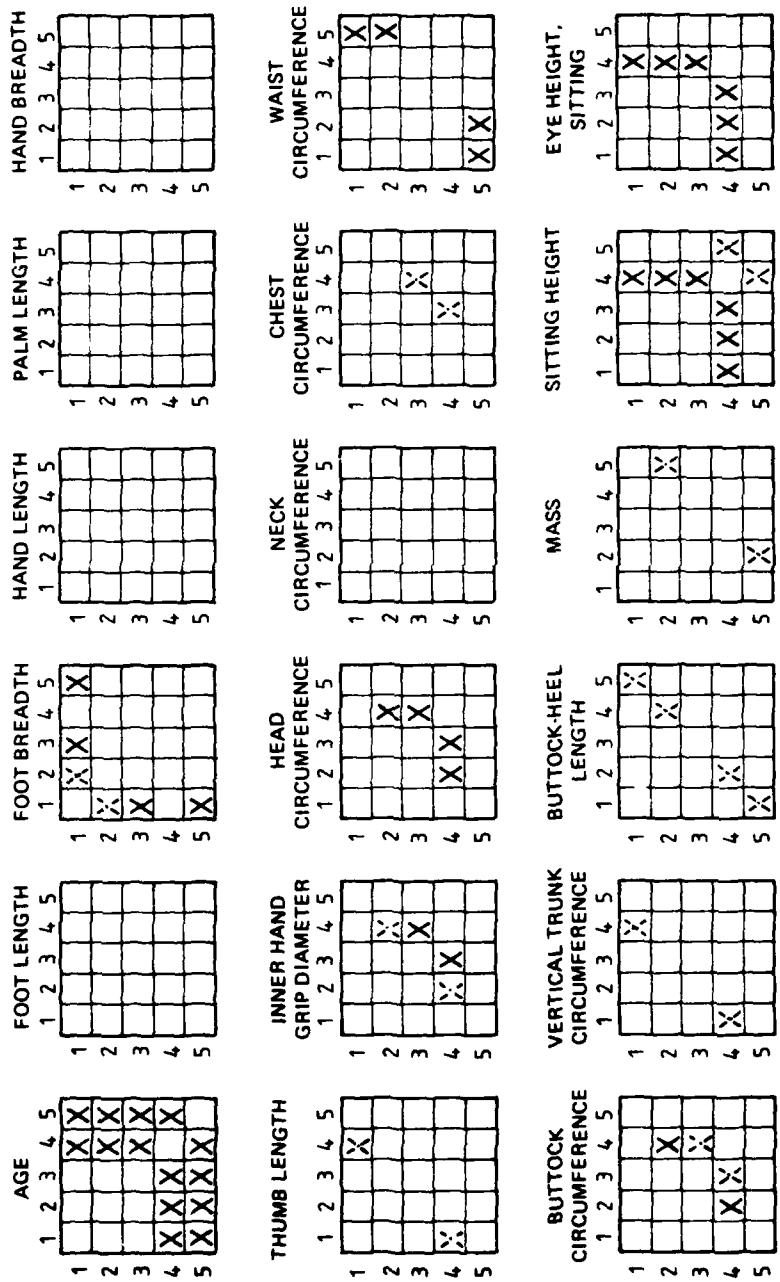
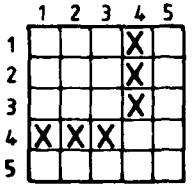

CHEST DEPTH
HEAD BREADTH
INTER-ELBOW BREADTH

TABLE 5: INTRASERVICE COMPARISONS – NAVY

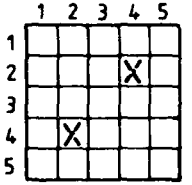
GROUPS
1. CLEARANCE DIVERS
2. CONSOLIDATION
3. COOKS
4. FLEET AIR ARM
5. SUBMARINERS



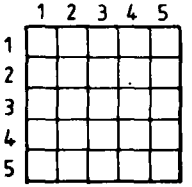
SHOULDER HEIGHT



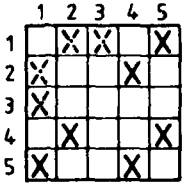
ACROMIAL HEIGHT



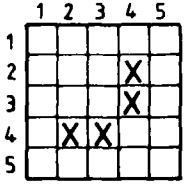
ELBOW REST HEIGHT



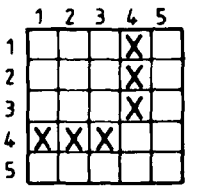
POPLITEAL HEIGHT



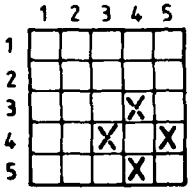
BIDELTOID BREADTH



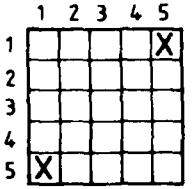
HIP BREADTH



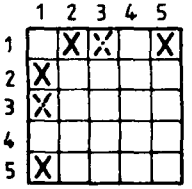
FUNCTIONAL REACH



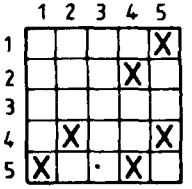
BUTTOCK-KNEE LENGTH



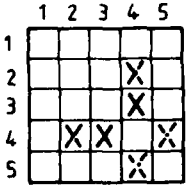
THIGH CLEARANCE HEIGHT



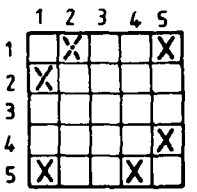
STOOL HEIGHT



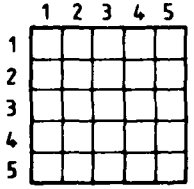
STATURE



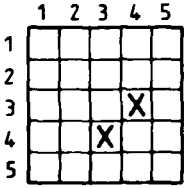
CROTCH HEIGHT



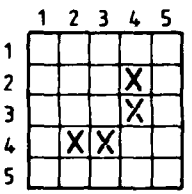
CHEST DEPTH

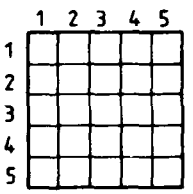


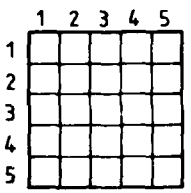
HEAD BREADTH

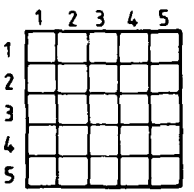


INTER-ELBOW BREADTH









6.1.1 Air Force

Aircrew (Group 2) appear as a distinct group, showing consistent differences in leg lengths and sitting heights from the other groups. In most respects Air Traffic Controllers (Group 1) show similar characteristics to the Aircrew group. In no cases do Air Traffic Controllers and Aircrew show differences significant at the 0·01 level; however, Air Traffic Controllers do not always show the same strong differences (as judged by the magnitude of the D statistic) as do Aircrew with respect to the other groups. When this occurs the value of D for the Aircrew/Air Traffic Controllers comparison is usually large but does not reach statistical significance (at either 0·01 or 0·025 levels). Hence, for these and historical reasons, it seems appropriate to keep the Aircrew group separate from all the other groups including Air Traffic Controllers.

The Transportation group (Group 5) shows significant (0·01) and large (0·025) differences from Groups 1, 2 and 3 for a number of measurements. Similarly, the Group 5/7 comparison reaches significance (0·01) on one occasion (Chest Depth) while the Group 5/4 combination gave large D values (0·025) on three occasions. In addition, Group 6 (Catering) differs from the other groups in a similar manner to Group 5 with the Group 5/6 comparison reaching significance (0·01 or 0·025) on the one occasion (Age) only. Hence, despite what at first sight seems an unlikely union, a combination of Groups 5 and 6 separate from Group 2 and Groups 1, 3, 4 and 7 appears to be justified.

Groups 2, 5 and 6 have been those groups showing the more consistent trends. The remaining groups (1, 3, 4 and 7) do not show consistent intergroup differences to an extent where further separation was considered to be justified. Hence, Groups 1, 3, 4 and 7 were combined to form a single group. Thus, three distinct groups remain from this process of amalgamation, viz.:

Aircrew (Group 2)

Transport and Catering (Groups 5 and 6);

Technical and Clerical (Groups 1, 3, 4 and 7).

6.1.2 Army

The Aviation group (Group 4) shows consistent differences from the other groups, particularly for Stature and seated heights. Therefore, the Aviation group was separated from the other groups with some confidence.

With the exception of Group 5 (for Waist Circumference) the remaining groups show weak trends only. Hence, Groups 1, 2 and 3 were combined as they show no significant intergroup differences (at 0·01 or 0·025) except in the case of Groups 1 and 3 (Age). This leaves Groups 5 and 6 to be considered.

It was decided to keep Groups 5 and 6 separate despite the lack of significant (at 0·01) D values on any dimension. Group 5 showed a consistent difference in Waist Circumference when compared to the other groups. Also the D values for the Group 5/6 comparisons were large, although not significant, for related girth, mass and stature measurements.

Hence, the following groups were considered to be unique:

Aviation (Group 4);

Catering (Group 5);

Technical (Group 6);

Weapon Users and Others (Groups 1, 2 and 3).

6.1.3 Navy

Again the Aircrew group stood alone from the other groups, hence the Fleet Air Arm (Group 4) subjects were segregated for separate analysis.

Clearance Divers (Group 1) showed a reasonably consistent trend of differences from the other groups, particularly for those measurements related to limb size.

The intergroup differences existing between the remaining groups (2, 3 and 5) reached statistical significance (at 0·01) for one case only, viz. Groups 2 and 5 for Waist Circumference. Although, for these same groups, D was large (0·025) for Mass as well, no further separation was considered to be warranted. Hence, those groups identified for separate analysis were:

Fleet Air Arm (Group 4);

Clearance Divers (Group 1);

Consolidation (Groups 2, 3 and 5).

TABLE 6: INTERSERVICE COMPARISONS – AIRCREW

GROUPS
1. AIR 3. NAVY
2. ARMY

TABLE 7: INTERSERVICE COMPARISONS – TRANSPORTATION

GROUPS
1. AIR 2. ARMY

AGE	FOOT LENGTH	FOOT BREADTH	HAND LENGTH	PALM LENGTH	HAND BREADTH	THUMB LENGTH
INNER HAND GRIP DIAM.	HEAD CIRCUM.	NECK CIRCUM.	CHEST CIRCUM.	WAIST CIRCUM.	BUTTOCK CIRCUM.	V. TRUNK CIRCUM.
BUTT-HEEL LENGTH	MASS	SITTING HEIGHT	EYE HEIGHT, SITTING	SHOULDER HEIGHT	ACROMIAL HEIGHT	ELBOW REST HEIGHT
POPLITEAL HEIGHT	BIDELTOID BREADTH	HIP BREADTH	FUNCTIONAL REACH	BUTT-KNEE LENGTH	THIGH CLEAR. HEIGHT	STOOL HEIGHT
STATURE	CROTCH HEIGHT	CHEST DEPTH	HEAD BREADTH	INTER-ELBOW BREADTH		

TABLE 8: INTERSERVICE COMPARISONS – TECHNICIANS

GROUPS
1. AIR 2. ARMY 3. NAVY

6.2 Interservice Comparisons

In three areas there was the possibility that there may be an interservice commonality between the members of various functional (trade) groups, viz.:

(*a*) Aviation;

(*b*) Transportation; and

(*c*) Technical Personnel.

The Kolmogorov–Smirnov two-sample test was applied to these data, yielding the results summarised in Tables 6, 7 and 8. Only the aircrew groups were considered to justify amalgamation.

6.3. Final Group Composition for Analysis

The process of amalgamation of similar groups described in the previous sections reduced the number of groups for separate analysis from the original 18 to 8. The composition of these groups, combined from the original groups, is indicated in Table 9.

TABLE 9
Composition of Unique Groups for Analysis

Combined groups	No.	Constituent groups		
		Army	Navy	Air Force
Aircrew	456	4	4	2
ARMY				
Cooks	190	5		
Technical Personnel	211	6		
Weapon Users and Others	555	1, 2, 3		
NAVY				
Clearance Divers	82		1	
Consolidation	509		2, 3, 5	
AIR FORCE				
Transport and Catering	312			5, 6
Technical and Clerical	630			1, 3, 4, 7
Total	2945			

7. DATA ANALYSIS

The regrouped and validated data were analysed to produce summarising statistics and percentile data in both tabular and graphical formats. Because of the small sample sizes some form of smoothing of the raw data was considered necessary in order to compute percentile tables. In a previous treatment of similar data (Ref. 1) ARL investigated three smoothing techniques, viz. Normal, Gram-Charlier and a polynomial fit in the Normal probability domain. Although at that time no advantage was seen for the other methods over a simple Normal fit to the data, the use of a fourth order Gram-Charlier fit was considered to be potentially useful and worthy of further investigation. The fourth order Gram-Charlier series extends the simple Normal fit by being sensitive to skewness and kurtosis in the data to be represented.

The Gram-Charlier model was applied to the data from the present survey with, in some cases, disappointing results. Some of the distributions to be fitted were characterised by a second

peak in the positive tail of their spectral density functions (mainly for the mass and girth measurements). Five terms (up to fourth powers) of the Gram-Charlier functions are not sufficient to fit, accurately, these double humped distributions as the fitting functions tend to be inappropriately leptokurtic in order to accommodate the positive tail.

A third order Gram-Charlier fit was finally used for the computation of the percentile tables reported in Parts 2 to 9 of Reference 8. The third order model was chosen for its ability to fit the consistently positively-skewed mass-related spectral density functions while avoiding the difficulties previously encountered with the fourth order system.

8. REPEATABILITY OF MEASUREMENTS

In order to assess the variability of the measuring technique, 50 subjects were remeasured on an opportunity basis. An error function (equal to the difference between the first and second measures) was computed and then the first four moments (about the mean) of the error

TABLE 10
Check Measure Repeatability Data

Parameter	Error function						
	Mean	S.D.	Skew.	Kurt.	Large.+	Large.−	Corr.
Foot Length	0·38	1·47	−0·03	0·70	4	−3	0·992
Foot Breadth	0·52	2·38	0·79	0·81	7	−4	0·906
Hand Length	−0·16	1·55	0·24	0·13	4	−4	0·985
Palm Length	−0·12	1·65	0·00	−0·92	3	−3	0·955
Hand Breadth	0·06	1·94	0·03	−0·20	5	−4	0·902
Thumb Length	−0·44	2·31	−0·77	0·93	4	−8	0·831
Inner Hand Grip Circum.	0·06	2·63	0·78	2·28	9·4	−6·3	0·979
Head Circumference	0·20	6·16	−0·74	2·64	17	−22	0·921
Neck Circumference	0·64	5·89	0·21	−0·63	14	−11	0·964
Chest Circumference	2·70	10·20	−0·49	0·17	23	−25	0·991
Waist Circumference	0·16	10·90	0·85	2·14	40	−20	0·995
Buttock Circumference	0·86	8·76	−0·34	−0·08	17	−23	0·993
Vertical Trunk Circum.	−0·62	14·50	−0·54	0·14	29	−38	0·982
Buttock–Heel Length	0·18	5·48	−0·32	−0·23	11	−13	0·994
Mass	0·04	0·71	−0·14	4·35	2·5	−2·5	0·998
Sitting Height	−3·32	8·44	−0·91	0·81	9	−32	0·950
Eye Height, Sitting	−4·44	10·30	−0·45	−0·57	15	−25	0·926
Shoulder Ht., Sitting	−1·98	7·70	−0·42	−0·27	14	−20	0·945
Acromial Ht., Sitting	−0·84	10·10	−0·47	−0·42	17	−23	0·899
Elbow Rest Height	−3·98	12·60	−1·82	5·52	13	−60	0·852
Popliteal Height	−0·24	4·81	−0·42	−0·50	10	−11	0·977
Bideltoid Breadth	1·60	5·62	−0·11	0·16	16	−13	0·981
Hip Breadth	0·38	5·55	0·41	0·76	15	−13	0·980
Functional Reach	−1·10	11·90	0·20	0·26	30	−27	0·949
Buttock–Knee Length	0·28	5·57	−0·53	0·32	10	−15	0·974
Thigh Clearance Height	0·22	4·87	0·21	0·67	12	−11	0·946
Stool Height	0·26	9·72	−0·47	2·34	27	−33	0·918
Stature	−0·22	2·69	−0·10	1·05	6	−8	0·999
Crotch Height	0·74	10·40	0·31	0·08	29	−22	0·969
Chest Depth	−0·02	4·77	−0·31	−0·36	8	−11	0·975
Head Breadth	0·06	2·28	−1·45	6·08	5	−10	0·910
Inter-Elbow Breadth	0·00	12·00	0·81	1·42	37	−25	0·971

distribution function were calculated, together with the Pearson correlation coefficient (Ref. 9). In addition the largest (numerically) positive and negative errors were derived. The results of this analysis are shown in Table 10. Note that in this table the third and fourth moments about the mean have been converted to coefficients of skewness ($\gamma_1 = \mu_3$) and kurtosis ($\gamma_2 = \mu_4 - 3$).

Thumb Length, Acromial Height and Elbow Rest Heights were the least reliable of the measures, with test–retest correlation coefficients of 0·831, 0·899 and 0·852 respectively. In addition the five sitting heights all have a negatively shifted mean error, suggesting that subjects' postures were more upright during the remeasuring procedure. This is a surprising result as it might be expected that subjects would be more relaxed the second time, due to their greater familiarity with the equipment and the procedures.

The 50 subjects used to test the repeatability of the measuring technique (including experimenter variation, both intra and inter) were selected without obvious bias from the various functional groups during the total time course of the survey (subject numbers ranged from 281 to 2502). Hence, the estimates of error function distribution have been assumed to be representative of measurement variation for any of the groups involved in this survey. To estimate the extent to which measurement reliability contributes to total measurement variances, ratios of measurement standard deviation to error function standard deviation were computed for the Aircrew group. These ratios range from 1·65 (Thumb Length) to 21·6 (Stature) with a mean value of 4·7. Thus, for some measurements at least, a large part of the measurement variance appears to be vested in the measurement repeatability itself.

9. CONCLUSIONS

This survey differed from most previously reported surveys in the method of subject selection. The stratification procedure used in determining the sample placed emphasis on measuring selected persons. As expected, some of the nominated subjects were not available for measuring, hence the substitution scheme described in Section 2 was implemented. The final substitution rate for the survey was 40·7% (for all branches and all groups) while the wastage was only 3·7% (i.e. subject not available, nor could a suitable substitute be provided).

The original intention to validate data 'on-line' was not met in this survey for reasons discussed in Section 5 of this document. This requirement to check data would be less critical if anthropometric measuring equipment could be fully automated (at least to the extent of automatically recording the measurement data). However, if small samples are to be used, with the present types of measuring devices, it is considered that every effort should be made to ensure the accuracy of the raw data. This is particularly important if data smoothing techniques are to be applied that use higher order moments in their determination. Even if 'on-line' checking is not used the time delay between measurement and validation can be reduced if data are gathered in machine compatible form (e.g. marked cards or magnetic tape). This procedure has a further advantage if it reduces the number of times the data are manually handled.

Accepting the limitations of conventional anthropometric measuring apparatus, considerable care was used in the design of the equipment and techniques in an effort to achieve consistency without unduly extending measuring time. A number of devices was used to aid in the initial positioning of the subject, and subsequently in the maintenance of that position. The generally high correlation coefficients for the test–retest comparisons reflect this care.

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APPENDIX I

Measurements and Definitions

Foot Length: Subject stands with his left foot in the foot-box, heel against the back wall and the medial side of the foot in contact with the side wall of the box. The datum edge is brought up to touch the most prominent toe. Record the distance of the datum edge from the back wall of the foot-box.

Foot Breadth: Subject stands with his left foot in the foot-box, heel against the back wall and the medial side of the foot in contact with the side wall of the box. The datum edge is brought into light contact with the widest aspect of the foot. Record the distance of the datum edge from the side wall of the foot-box.

Hand Length: Subject's left hand is fully extended and supinated in the axis of the forearm, fingers together. With the bar of the sliding calipers parallel to the longitudinal axis of the hand, measure the distance from the tip of the third digit to the wrist mark at the first major skin crease proximal to the base of the hypothenar eminence.

Palm Length: Subject's left hand is fully extended and supinated in the axis of the forearm, fingers together. With the bar of the sliding calipers parallel to the longitudinal axis of the hand, measure the distance from the skin fold at the junction of the third digit and the palm of the hand to the wrist mark at the first major skin crease proximal to the base of the hypothenar eminence.

Hand Breadth: Subject's left hand is fully extended and supinated in the axis of the forearm, fingers together with the thumb held away from the hand. Using the sliding calipers measure the distance across the distal ends of the metacarpal bones.

Thumb Length: Subject's left hand is fully extended and pronated in the axis of the forearm, fingers together with the thumb held away from the hand. With the bar of the sliding calipers parallel to the longitudinal axis of the thumb, measure the distance from the tip of the thumb to the thumb mark at the first metacarpophalangeal joint.

Inner Hand Grip Circumference: The measuring device is a cone of linearly increasing diameter. The subject grips the cone firmly from behind with the left hand at the maximum diameter at which the thumb and third digit may be lightly opposed. The point of opposition lies over the line scribed on the front of the cone. Inner Hand Grip Circumference is the circumference of the cone in a horizontal plane containing the point of opposition.

Head Circumference: Subject sits erect, looking straight ahead. Measure the maximum head circumference, the tape passing just over the brow ridges and over the occiput, using just sufficient tape tension to flatten the hair.

Neck Circumference: Subject sits erect, looking straight ahead. Measure the circumference of the neck ensuring that the tape is at right angles to the longitudinal axis of the neck and that the datum edge of the tape passes over the tip of the thyroid cartilage.

Chest Circumference: Subject stands erect, feet approximately 100 mm apart, with arms away from the sides. The tape is passed horizontally around the chest, aligning the datum edge with the nipples and the chest marks made on the subject's back. The arms are lowered, tape alignment checked and Chest Circumference measured at the end of a normal inspiration.

Waist Circumference: Subject stands erect, heels approximately 100 mm apart, with arms away from the sides. The tape is passed horizontally around the waist, aligning the datum edge with the umbilicus and the waist marks made on the subject's back. The arms are lowered, tape alignment checked, and Waist Circumference measured.

Buttock Circumference: Subject stands erect, feet together. Measure Buttock Circumference with the tape passing horizontally around the maximum posterior protuberance of the buttocks.

Vertical Trunk Circumference: Subject stands erect, looking straight ahead, heels approximately 100 mm apart and the arms relaxed by the sides. Measure Vertical Trunk Circumference, passing the tape back over the left shoulder, the datum edge aligned with the 90 mm shoulder mark, down between the buttocks, through the crotch to the left of the genitals and up the front of the trunk spanning all body hollows. Adjust the tape tension so that firm pressure is applied to the crotch without indenting the shoulder.

Buttock-Heel Length: Subject sits on the measuring rig with both legs out straight and the knees locked. The subject is instructed to '. . . push your buttocks as far as possible into the back wall'. Before the subject relaxes, the foot block is brought up the left heel and the distance of the datum edge from the rear wall of the measuring device is recorded.

Mass: The mass of the subject is recorded standing on a spring scale (subject wearing briefs only).

Adjust Hydraulic Stool: The height of the stool is adjusted so that with the subject sitting erect and back free of the wall, the line joining the upper and lower femoral-marks is horizontal and with the feet flat on the floor the line joining the upper and lower fibular-marks is vertical.

Sitting Posture: Without changing the position of the legs after adjusting the hydraulic stool, the subject sits erect, back free of the wall with the trunk straight, upper arms vertical, elbows resting lightly against the sides and the forearms extended so that the hands rest on mid-thighs. The shoulders are equally relaxed.

To assist the subject in maintaining this posture a sighting device is brought up in front of the subject. The upper sightline is adjusted until the reflections of the sightline and the centre of the subject's pupils, in the mirror opposite, coincide. Similarly, the lower sightline is adjusted until the reflections of this line and the subject's nipples are seen to coincide in the mirror.

Sitting Height: The subject holds the sitting posture. The datum edge is brought down in the midsagittal plane until light contact is made with the vertex. Record the height of the datum edge from the floor. Sitting Height equals the datum height less Stool Height.

Eye Height (sitting): The subject holds the sitting posture. The datum line is brought up until the reflections of this line and the centre of the subject's left pupil, in the mirror opposite, are coincident. Record the height of the datum line from the floor. Eye Height equals the datum height less Stool Height.

Shoulder Height (sitting): The subject holds the sitting posture. The datum edge is brought down until light contact is made with the 90 mm mark on the left shoulder. Record the height of the datum edge from the floor. Shoulder Height equals the datum height less Stool Height.

Acromial Height (sitting): The subject holds the sitting posture. The datum edge is brought down until light contact is made with the left acromial mark. Record the height of the datum edge from the floor. Acromial Height equals the datum height less Stool Height.

Elbow Rest Height: The subject holds the sitting posture except that the forearms are raised and extended forwards horizontally. The hands and fingers are extended in the vertical plane containing the forearm. The datum edge is brought up to make contact with the lower edge of the left olecrannon. Record the height of the datum edge from the floor. Elbow Rest Height equals the datum height less Stool Height.

Popliteal Height: The subject holds the sitting posture. With the sliding calipers measure the vertical distance from the floor to the underside of the tendon of the left biceps femoris muscle where it joins the calf.

Bideltoid Breadth: The subject moves across to his right-hand side until the right deltoid muscle is brought into light contact with the perspex wall panel. The circle of skin in contact with the perspex has a diameter of approximately 30 mm (this is monitored in the mirror). The subject regains the sitting posture and the datum edge is moved horizontally until light contact is made with the most distal portion of the left deltoid prominence. Record the distance of the datum edge from the end wall.

Hip Breadth: Subject moves across to his right-hand side so that the fleshy part of his right hip makes light contact with the perspex wall panel (monitored in the mirror). The subject's knees are brought together; feet are flat on the floor. The datum edge is moved horizontally until light contact is made with the widest region of the left hip. Record the distance of the datum edge from the end wall.

Functional Reach: The subject sits erect looking straight ahead at the reflection of his pupils in the mirror directly in front of him. Both shoulder blades are symmetrically and lightly touching the perspex panel in the end wall of the measuring rig (monitored in the mirror). The arms are extended forward horizontally and the hand is pronated with the tip of the index finger touching the extended thumb (which is held in the plane of the extended arm). The datum edge is moved horizontally until contact is made with the tip of the left thumb. Record the distance of the datum edge from the end wall.

Buttock–Knee Length: The subject sits erect, feet flat on the floor and thighs parallel to the rear wall of the measuring rig. The subject is instructed to '. . . push your buttocks back until you have equal pressure on both buttocks against the perspex wall'. Both shoulder blades are symmetrically and lightly touching the perspex panel in the end wall of the measuring rig. The datum edge is moved horizontally until contact is made with the most forward prominence of the left patella. Record the distance of the datum edge from the end wall.

Thigh Clearance Height: The subject sits erect, fee tflat on the floor, arms hanging vertically and lightly touching the sides. The datum edge is brought down to make light contact with the highest point on the left thigh. Record the height of the datum edge from the floor. Thigh Clearance Height equals the datum height less Stool Height.

Stool Height: The subject stands and moves away from the stool. The datum edge is brought down to make contact with the upper surface of the stool seat. Record the height of the datum edge from the floor.

Stature: The subject stands erect, looking straight ahead, heels together and back free of the wall. The datum edge is brought down in the midsagittal plane until light contact is made with the vertex. Record the height of the datum edge from the floor.

Crotch Height: The subject stands erect looking straight ahead with heels approximately 100 mm apart. The datum edge is pushed up into the floor of the perineum, taking care not to impinge on the buttocks or the genitals. Record the height of the datum edge from the floor.

Chest Depth: The subject stands erect with arms relaxed by the sides. With the bar of the sliding calipers held horizontally and parallel to the midsagittal plane at the level of the left nipple, measure Chest Depth at the end of a normal inspiration.

Head Breadth: The subject sits, looking straight ahead. With the sliding calipers held in a horizontal plane and applying sufficient pressure with the jaws of the calipers to flatten the hair, measure the maximum head breadth in the coronal plane.

Inter-Elbow Breadth: The subject sits erect, upper arms vertical, elbows lightly touching the sides, forearms extended forwards horizontally and palms resting lightly on the support bar. With the sliding calipers measure the horizontal distance between the most distal projections of the lateral epicondyles of the humeri.

Prior to measuring, various measurement landmarks were marked on the subjects. These were as follows:

(i) 90 mm shoulder mark (from midsagittal plane);

(ii) distal edge of the left acromial process;

(iii) great trochanter at the head of the left femur;

(iv) lateral condyle at the base of the left femur;

(v) head of the left fibular;

(vi) left lateral malleolus;

(vii) wrist mark at the first major skin crease proximal to the base of the hyperthenar eminence;

(viii) thumb mark at the first metacarpophalangeal joint (left thumb);

(ix) a line on the subject's back at the height of the left nipple;

(x) a line on the subject's back at the height of the umbilicus.

With the exception of (ix) and (x) all marks were made with the subject sitting. Bony landmarks were located by palpation.

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